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Gravitational wave propagation beyond general relativity: waveform distortions and decoherence

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We study the cosmological propagation of gravitational waves (GW) beyond general relativity (GR) across homogeneous and isotropic backgrounds. We consider scenarios in which GWs interact with an additional tensor field and use a parametrized phenomenological approach that generically describes their coupled equations of motion. We analyze four distinct classes of derivative and non-derivative interactions: mass, friction, velocity, and chiral. We apply the WKB formalism to account for the cosmological evolution and obtain analytical solutions to these equations. We corroborate these results by analyzing numerically the propagation of a toy GW signal. We then proceed to use the analytical results to study the modified propagation of realistic GWs from merging binary black holes, assuming that the GW signal emitted is the same as in GR.
We generically find that tensor interactions lead to copies of the originally emitted GW signal, each one with its own possible modified dispersion relation.
These copies can travel coherently and interfere with each other leading to a scrambled GW signal, or propagate incoherently and lead to echoes arriving at different times at the observer that could be misidentified as independent GW events.
Depending on the type of tensor interaction, the detected GW signal may exhibit amplitude and phase distortions with respect to a GW waveform in GR, as well as birefringence effects.
We discuss observational probes of these interactions with both individual GW events, as well as population studies for both ground- and space-based detectors.

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